MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY/BRIDGE PROGRAMS
GEOTECHNICAL SECTION
AUGUSTA, MAINE

GEOTECHNICAL DESIGN REPORT

For the Replacement of:

ROUTE 27 LARGE CULVERT
SOUTHPORT, MAINE

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Geotechnical Engineer

Lincoln County | Soils Report No. 2015-10
WIN 22548.00
May 21, 2015

PROJECT DETAILS

The purpose of this report is to present the subsurface information and make geotechnical recommendations for the replacement of twin, 4-foot corrugated metal pipes which carry an unnamed stream under Route 27 in Southport. The culverts are located 0.33 miles northeast of Joppa Road as shown in the attached Location Map. The unnamed stream outlets into Love Cove in Southport. Route 27 is a Priority 5 Highway Corridor. The current culverts will be replaced by a single 8-foot span by 3-foot rise, three-sided precast concrete box culvert. The structure will be lengthened from approximately 50.5 feet to approximately 56 feet. The roadway will have 11-foot travel lanes and 3-foot paved shoulders, and guardrail will be added on both sides of the road with pavement extending 1-foot behind the guardrail posts. The precast concrete box culvert inlet and outlet slopes will be riprapped with slopes of 2H:1V to protect against erosion.

SUBSURFACE CONDITIONS

Two (2) borings were drilled for this project (HB-SCR-101 and HB-SCR-102). The boring locations are shown on the attached Geoplan & Interpretive Subsurface Cross Section. Boring HB-SCR-102 encountered approximately 5-inches of Hot Mix Asphalt pavement at the ground surface. No pavement was present at boring HB-SCR-101. A layer of roadway fill was encountered in both of the borings. The thickness of the fill ranged from approximately 5.6 feet to 6.8 feet at the boring locations. The upper portion of the fill consisted of roadway subbase material which was approximately 2-feet thick. The remaining fill material consisted of brown, damp, dense to medium dense, sandy gravel, little silt. No laboratory soil testing was performed for this project.

Bedrock was encountered at depths of approximately 6.0 to 6.8 feet below ground surface at the boring locations. The bedrock is identified as milky white and tan, coarse grained, fresh to slightly weathered, pegmatite of the Cape Elizabeth Formation. Close to moderately spaced horizontal breaks, which are rough, fresh to discolored, and partially open to open were observed in the rock core. The Rock Quality Designation (RQD) of the bedrock was determined to be 70 and 90% which correlates to a Rock Mass Quality of fair to good.

Groundwater was not observed in the borings. Groundwater levels can be expected to fluctuate subject to seasonal variations, local soil conditions, topography, precipitation, and construction activity.

Details of the sampling methods used, field data obtained and soil conditions encountered are presented in the attached boring logs. Photographs of the rock core are also attached to this report.

GEOTECHNICAL DESIGN AND CONSTRUCTION RECOMMENDATIONS

Precast Concrete Box Culvert Design and Construction - Due to the presence of shallow bedrock it is likely that bedrock removal will be necessary for installation of the precast concrete box culvert. Excavation of bedrock material may be done using conventional excavation methods, but may require drilling and blasting techniques.

The precast concrete box culvert shall be supplier-designed in accordance with AASHTO LRFD Bridge Design Specifications 7th Edition 2014 (LRFD) and Special Provision 534 Precast Concrete Arches, Box Culverts. The precast concrete box culvert shall be designed for all relevant strength and service limit states and load combinations specified in LRFD Article 3.4.1 and LRFD Section 12. The precast concrete box culvert shall be constructed in conformance with MaineDOT BDG Section 8 and Special Provision 534.

Precast concrete box culverts are typically detailed on the contract plans with only the basic layout and required hydraulic opening so that the Contractor may choose the appropriate structure. The manufacturer is responsible for the design of the structure including determination of the wall thickness, haunch thickness and reinforcement. The designer should use Soil Type 4 as presented in the MaineDOT Bridge Design Guide (BDG) Section 3.6 to design earth loads from the soil envelope. The backfill properties are as follows: ϕ = 32 degrees, γ = 125 pcf.

The precast concrete box culvert soil envelope and backfill shall consist of Standard Specification 703.19 - Granular Borrow Material for Underwater Backfill with a maximum particle size of 4 inches. The granular borrow backfill should be placed in lifts of 6 to 8 inches thick loose measure and compacted to the manufacturer's specifications. In no case shall the backfill soil be compacted less than 92 percent of the AASHTO T-180 maximum dry density.

Precast Concrete Box Culvert Headwalls - Concrete headwalls should be included in the precast concrete box culvert design to retain riprap slopes and prevent riprap from dropping or eroding into the waterway. A nominal 1 foot by 1 foot concrete headwall is recommended.

Cast-in-Place Footings on Bedrock - Bedrock was encountered at approximate elevation 6.2 feet in the vicinity of the proposed western footing and at approximate elevation 5.0 feet in the vicinity of the proposed eastern footing. Cast-in-place footings can be constructed to bear on bedrock within moderately shallow excavations possibly requiring cofferdams and temporary support systems. The borings indicate that bedrock with an RQD of approximately 70 to 90 percent will be encountered at the bedrock surface.

The bottom of footing elevations will vary based on the actual bedrock surface at the footing locations. The minimum thickness of the footing should allow for the inclusion of two (2) mats of reinforcing steel. The cast-in-place footings may be designed to vary in thickness to accommodate variations in the bedrock surface.

Bearing Resistance – Cast-in-place footings shall be proportioned to provide stability against bearing capacity failure. Application of permanent and transient loads is specified in LRFD Article 11.5.5. The bearing vertical stress shall be calculated assuming a triangular or trapezoidal pressure distribution over the effective base as shown in LRFD Figure 11.6.3.2-2 for foundations on rock.

The bearing resistance of cast-in-place spread footings constructed on bedrock shall be investigated at the service limit state using factored loads and a factored bearing resistance of 20 ksf. Resistance factors for the service limit state are taken as 1.0. A factored bearing resistance of 20 ksf shall be used to control settlement when analyzing the footing for the service limit state load combination and for preliminary footing sizing as allowed in LRFD Article C10.6.2.1.

The bearing resistance for cast-in-place footings constructed on bedrock shall be investigated at the strength limit state using factored loads and a factored bearing resistance of 16 ksf. This assumes a bearing resistance factor, φ_b, for spread footings on bedrock of 0.45, based on bearing resistance evaluation using semi-empirical methods. Calculations are attached to this report.

In no instance shall the bearing stress exceed the nominal structural resistance of the structural concrete which may be taken as $0.3f'c$. No footing shall be less than 2 feet wide regardless of the applied bearing pressure or bearing material.

Cast-in-Place Footing Design - Cast-in-place spread footings for the precast concrete box culvert shall be designed for all relevant service, strength, and extreme limit state load combinations specified in LRFD Articles 3.4.1, 11.5.5 and 12.5. Spread footings shall be designed to resist all lateral earth loads, vehicular loads, dead loads and lateral thrust forces transferred through the precast concrete box culvert.

For the service limit state a resistance factor, φ, of 1.0 shall be used to assess spread footing design for settlement, horizontal movement, bearing resistance, sliding and eccentricity. The overall stability of foundations is typically investigated at the Service I Load Combination and a resistance factor, φ, of 0.65. Shear failure along adversely oriented joint surfaces in the rock mass below the foundations is not anticipated, therefore, a global stability evaluation may be waived.

For the strength and extreme limit state the design of spread footings shall consider bearing resistance, eccentricity, lateral sliding and reinforced concrete structural failure. Extreme limit state design checks shall include those load combinations relating to certain hydraulic events and ice (if warranted by ice history or stream constriction by the structure). Resistance factors, φ, for the extreme limit state shall be taken as 1.0 with the exception of bearing for which a resistance factor of 0.8 shall be used.

For footings on bedrock, the eccentricity of loading at the strength limit state, based on factored loads, shall not exceed 0.45 of the footing dimensions in either direction. The eccentricity corresponds to the resultant of reaction forces falling within the middle nine-tenths (9/10) of the base width.

For sliding analyses, a sliding resistance factor, φ_τ, of 0.80 shall be applied to the nominal sliding resistance of cast-in-place footings founded on bedrock assuming the bedrock subgrade will be prepared in-the-wet and some amount of sediment will remain on the bedrock surface. If the bedrock subgrade is prepared in-the-dry and cleaned with high pressure water and air prior to placing footing concrete a sliding resistance factor, φ_τ, of 0.90 may be used. LRFD Table

11.5.7-1 allows a sliding resistance factor, φ_τ, of 1.0 for gravity and semigravity retaining walls regardless of subgrade material.

Anchorage of the footings to bedrock may be required to resist sliding forces and improve stability. Dowels should be #9 reinforcing bars or larger and embedded into the footings and bedrock by depths determined by the designer. If bedrock is observed to slope steeper than 4H:1V at the footing subgrade elevation, the bedrock should be benched to create level steps.

Bedrock Removal and Bedrock Subgrade Preparation - Construction activities should not be permitted to disturb the bedrock mass or to create any rockfalls or any open fissures. Any irregularities in the existing bedrock surface or irregularities created during the excavation process should be backfilled with unreinforced concrete to the bearing elevation. Footings may be stepped for varying depths to bedrock along the centerline of bearing. The bottom of footing elevation may vary based on the presence of fractured bedrock.

The nature, slope and degree of fracturing in the bedrock bearing surfaces will not be evident until the foundation excavations for the precast concrete box culvert footings are made. The bedrock surface shall be cleared of all loose fractured bedrock, loose decomposed bedrock, and soil. The final bearing surface shall be solid. The bedrock surface slope shall be less than 4H:1V or it shall be benched in level steps or excavated to be completely level. Anchors or dowels may also be designed and employed to improve sliding resistance where the prepared bedrock surface is steeper than 4H:1V in any direction.

The cleanliness and condition of the bedrock surface shall be approved by the Resident prior to placement of the footing concrete.

Where foundations are constructed in the dry, the final bearing surface shall be washed with high pressure water and air prior to concrete being placed for the footing. In-the-dry or underwater excavation of highly sloped and loose fractured bedrock material may be done using conventional excavation methods, but may require drilling and blasting techniques. Blasting should be conducted in accordance with Section 105.2.6 of the MaineDOT Standard Specifications. It is also recommended that the contractor conduct pre-and post-blast surveys, as well as blast vibration monitoring at nearby structures in accordance with industry standards at the time of the blast.

It is anticipated that there will be seepage of water from fractures and joints exposed in the bedrock surface. Water should be controlled by pumping from sumps. The contractor should maintain the excavation so that all foundations are constructed in the dry.

Settlement - No settlement issues are anticipated at the site. No changes to the existing vertical or horizontal alignment are currently planned for this project. All foundations will be constructed on bedrock. Any settlement of the foundations will be due to elastic compression of the bedrock and will be negligible.

Frost Protection - It is anticipated that the precast concrete box culvert spread footings will be cast directly on bedrock. For foundations on bedrock, heave due to frost is not a design issue and no requirements for minimum depth of embedment are necessary.

Scour and Riprap – For scour protection of the precast concrete box culvert footings, construct the footings directly on bedrock surfaces cleaned of all soil, and weathered, loose and potentially erodible or scourable rock. All loose rock, highly fractured bedrock or bedrock with gouge shall be removed by ripping. We anticipate that the remaining bedrock subgrade will be competent and is not considered erodible or scourable. No specific scour protection recommendations are needed for the foundations other than armoring with riprap.

Both the inlet and outlet of the precast concrete box culvert shall be protected against scour with riprap. The maximum slope of the riprap will be 2H:1V. The toe of the riprap section shall be constructed 1 foot below the streambed elevation unless the streambed consists of bedrock. The riprap section shall be underlain by a 1 foot thick layer of bedding material conforming to item number 703.19 of the Standard Specification and a Class “1” Erosion Control Geotextile per Standard Details 610(02) through 610(04) with a permittivity on the order of 0.1/sec to prevent clogging of the geotextile by fines.

Construction Considerations – Construction activities may include construction of cofferdams or earth support systems to control stream flow during construction.

The nature, slope and degree of fracturing in the bedrock bearing surfaces will not be evident until the foundation excavations are made. Construction activities should not be permitted to disturb the bedrock mass or create any open fissures. Irregularities in the existing bedrock surface or irregularities created during the excavation process should be backfilled with unreinforced concrete to the bearing elevation. Footings may be stepped for varying depths of bedrock along the centerline of the footing. The bottom of footing elevation will vary based on the presence of fractured bedrock.

The bedrock surface shall be cleaned of all soil, loose fractured bedrock, and loose decomposed bedrock. Bedrock may be removed by mechanical means including expansive agents, hydraulic hoe ram, hydraulic splitters, or wedging and prying. The final bearing surface shall be solid.

The bedrock surface slope shall be less than 4H:1V or it shall be benched in level steps or excavated to be completely level. Anchoring, doweling or other means of improving sliding resistance may also be employed where the prepared bedrock surface is steeper than 4H:1V in any direction.

Excavation of highly sloped and loose fractured bedrock material may be done using conventional excavation methods, but may require drilling and blasting techniques. Blasting should be conducted in accordance with Section 105.2.6 of the MaineDOT Standard Specifications. It is also recommended that the contractor conduct pre-and post-blast surveys, as well as blast vibration monitoring at nearby residences and bridge structures in accordance with industry standards at the time of the blast.

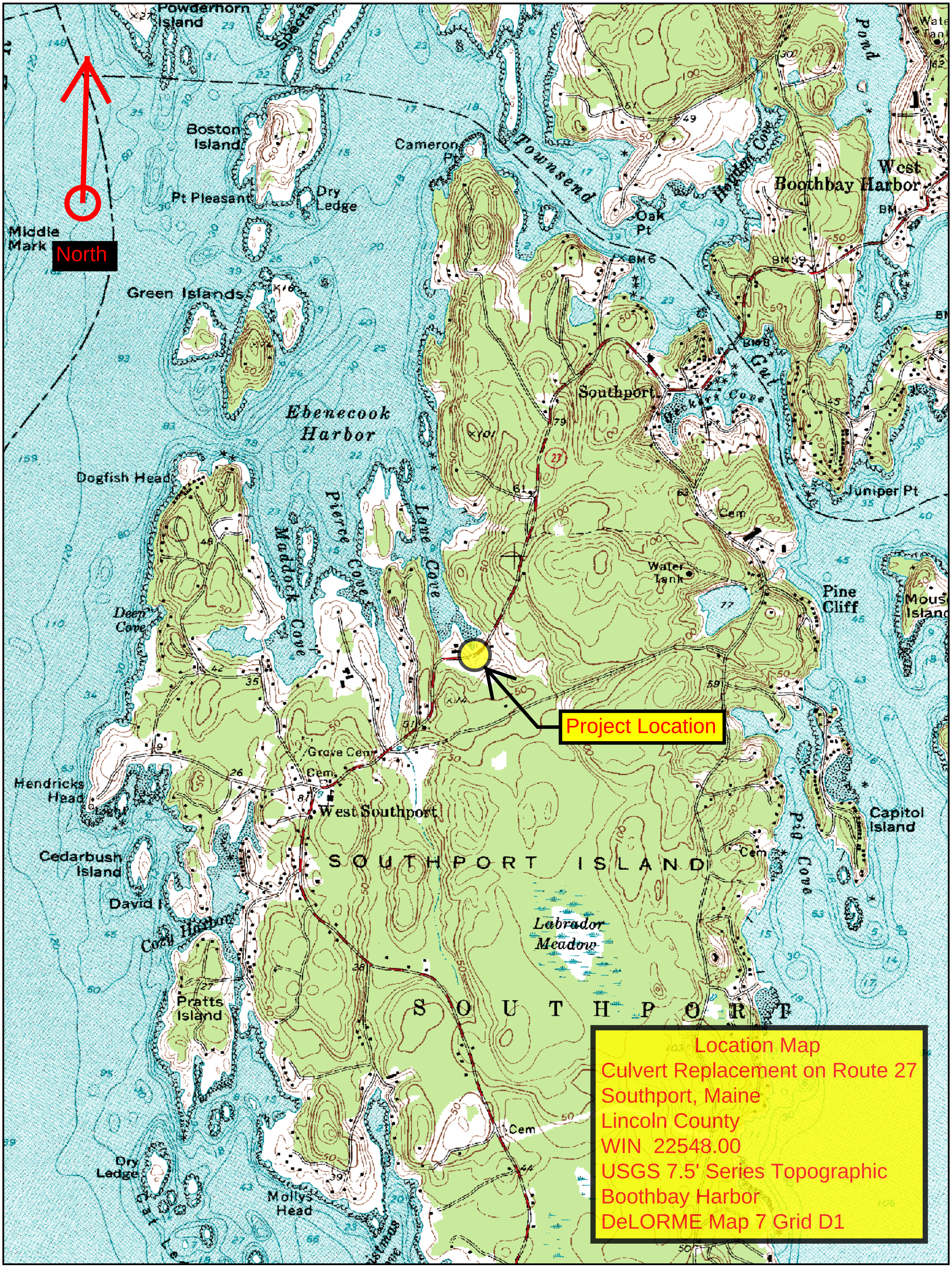
The cleanliness and condition of the bedrock surface shall be approved by the Resident prior to placement of the footing concrete.

It is anticipated that there will be seepage of water from fractures and joints exposed in the bedrock surface. Surface water should be diverted from the foundation excavation throughout construction. Water should be controlled by pumping from sumps outside the foundation footprint.

Using the excavated native soils as structural backfill should not be permitted. The native soils may only be used as common borrow in accordance with MaineDOT Standard Specifications 203 and 703.

Attachments:

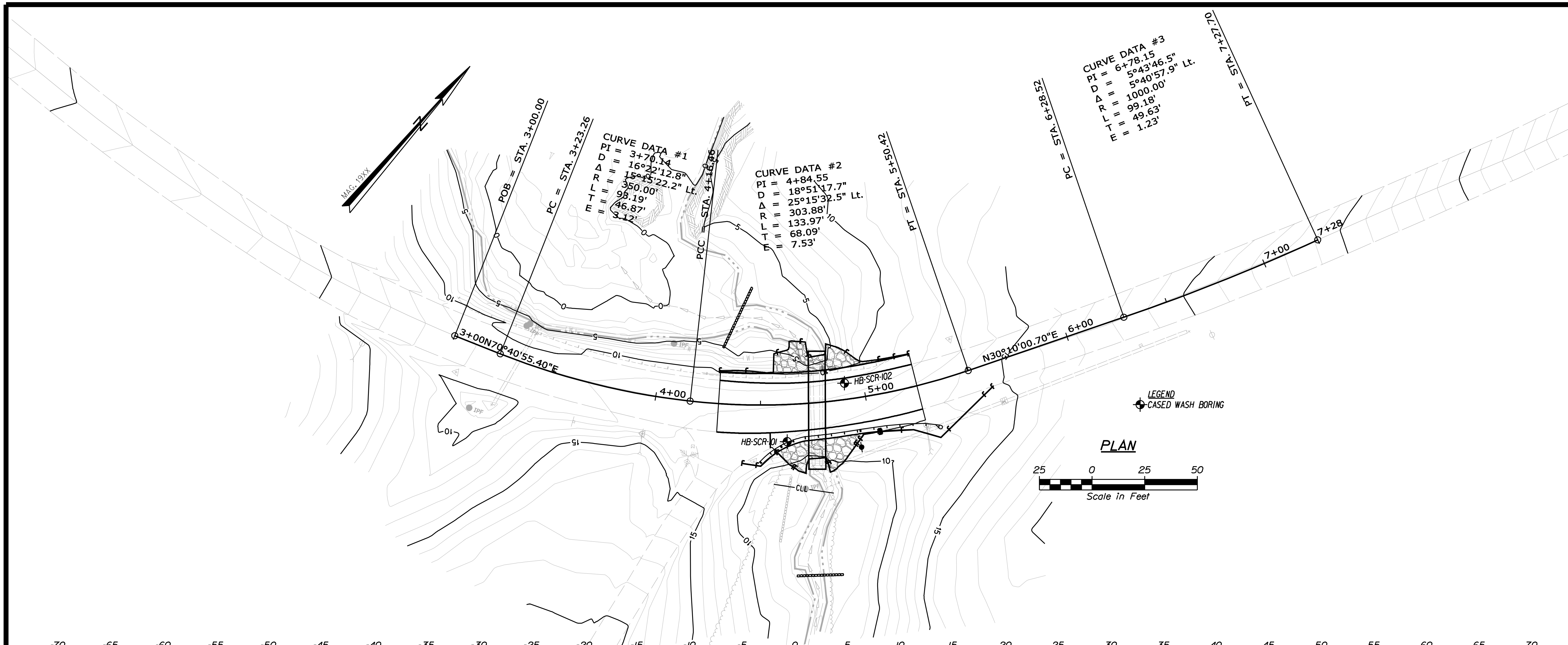
Location Map
GeoPlans & Interpretive Subsurface Cross Section
Boring Logs
Bedrock Core Photographs
Calculations

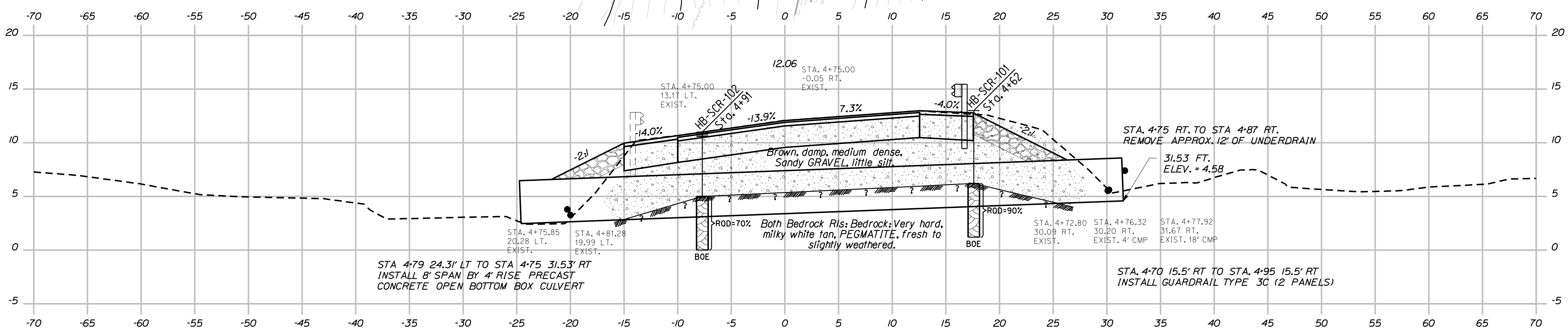


Map Scale 1:24000

The Maine Department of Transportation provides this publication for information only. Reliance upon this information is at user risk. It is subject to revision and may be incomplete depending upon changing conditions. The Department assumes no liability if injuries or damages result from this information. This map is not intended to support emergency dispatch. Road names used on this map may not match official road names.

Filename: ...\MSTA\001_Geoplan & ISCS1.dgn   Division: GEOTECH   Username: terry.white   Date:5/4/2015





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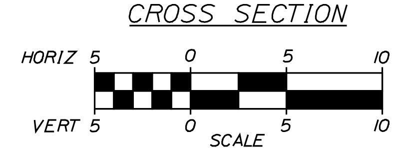
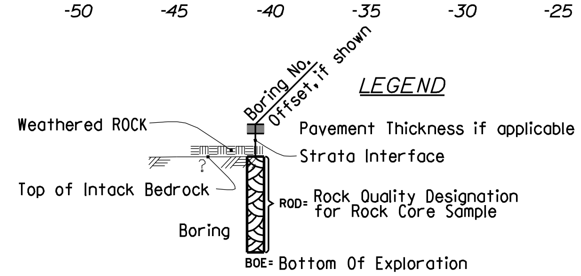
CROSS SECTION





Note: This generalized interpretive soil cross section is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and have been developed by interpretations of widely spaced explorations and samples. Actual soil transitions may vary and are probably more erratic. For more specific information refer to the exploration logs.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

022548.00

WIN 22548.00

HIGHWAY PLANS

	BY	DATE	
PROJ. MANAGER	S. SMITH		
DESIGN-DETAILED	N. HARTLEY		SIGNATURE
CHECKED-REVIEWED	M. KIRKMANN		
DESIGN2-DETAILED2	T. WHITE	MAY 2015	P.E. NUMBER
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			DATE
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SOUTHPORT
ROUTE 27

GEOPLAN & INTERPRETIVE
SUBSURFACE CROSS SECTION

SHEET NUMBER

1

OF _

Schonewald Engineering Associates, Inc.	PROJECT: Culvert Replacement Route 27 - Hendricks Hill Road LOCATION: Southport	Boring No.: HB-SCR-101 WIN: 22548.00

Driller:	New England Boring Contractors	**Elevation (ft.)**	13 ft. (est'd)	**Auger ID/OD:**	
Operator:	Schaefer/ Titus	**Datum:**		**Sampler:**	standard split-spoon
Logged By:	Schonewald	**Rig Type:**	Mobile Drill B-53, truck	**Hammer Wt./Fall:**	140# / 30", rope & cathead
Date Start/Finish:	4/8/15; 0910-1150	**Drilling Method:**	cased wash boring	**Core Barrel:**	NQ2
Boring Location:	Station 4+62, 17.6 RT (approx.)	**Casing ID/OD:**	NW (3-inch)	**Water Level*:**	--

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample attempt
V = Insitu Vane Shear Test
MV = Unsuccessful Insitu Vane Shear Test attempt

Definitions:
S_u = Insitu Field Vane Shear Strength (psf)
R = Rock Core Sample
RQD = Rock Quality Designation (%)
WOC = weight of casing
WOH = weight of 140lb. hammer
WOR = weight of rods

Definitions:
-- = not recorded
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
WC = water content, percent
-#200 = percent fines from grain size analysis

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Lab. Testing Results
0									Gravel shoulder	
									Boney - gravel and cobbles	
	1D	24/6	2.0 - 4.0	12-18-31-10	49				1D: Brown, damp, dense, fine to coarse Sandy GRAVEL, little Silt.	
5	2D	22/6	5.0 - 6.8	16-14-8-bouce	22				2D: Brown, damp, m. dense, fine to coarse Sandy GRAVEL, little Silt.	
	R1	60/60	6.8 - 11.8	RQD = 90%			6.2		6.8	
									R1: V. hard, fresh to slightly weathered, coarse grained, milky white tan, quartz-plagioclase-muscovite PEGMATITE, with flow bands containing mafic minerals and mafic content increasing with depth. Close to moderately spaced, horizontal breaks; typically undulating, rough, fresh to discolored, and partially open to open. Core times: 3:10/2:10/2:05/ 1:50/2:05 min:sec/ft.	
10										
							1.2		11.8	
									Bottom of Exploration at 11.8 feet below ground surface. Boring terminated approximately 5 feet into rock.	
15										
20										
25										

Remarks:

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.

SCHONEWALD ENGINEERING ASSOCIATES, INC.

PROJECT: Culvert Replacement
Route 27 - Hendricks Hill Road

LOCATION: Southport

Boring No.: HB-SCR-102

WIN: 22548.00

Driller:	New England Boring Contractors	**Elevation (ft.)**	11 ft. (est'd)	**Auger ID/OD:**	
Operator:	Schaefer/ Titus	**Datum:**		**Sampler:**	standard split-spoon
Logged By:	Schonewald	**Rig Type:**	Mobile Drill B-53, truck	**Hammer Wt./Fall:**	140# / 30", rope & cathead
Date Start/Finish:	4/8/15; 1200-1340	**Drilling Method:**	cased wash boring	**Core Barrel:**	NQ2
Boring Location:	Station 4+91, 7.7 LT (approx.)	**Casing ID/OD:**	NW (3-inch)	**Water Level*:**	--

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MV = Unsuccessful Insitu Vane Shear Test attempt

Definitions:
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Definitions:
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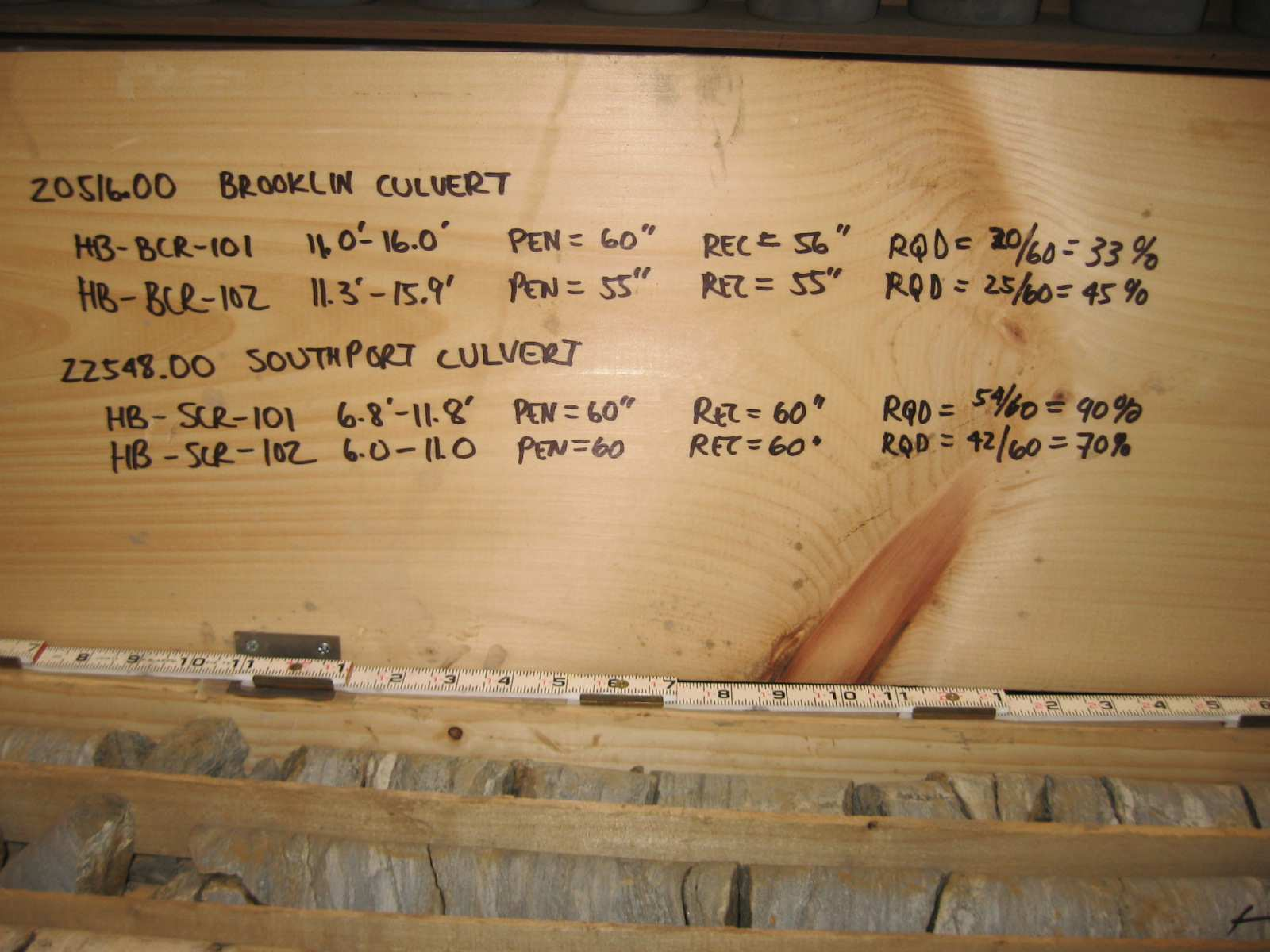
WC = water content, percent
-#200 = percent fines from grain size analysis

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Lab. Testing Results
0							10.6		5" HMA ——0.4	
									Advance through overburden without sampling. Cuttings appear to be granular FILL; boney (gravel and cobbles) throughout.	
5							5.0		——6.0	
	R1	60/60	6.0 - 11.0	RQD = 70%					R1: V. hard, fresh to slightly weathered, coarse grained, milky white tan, quartz-plagioclase-muscovite PEGMATITE, with flow bands containing mafic minerals and mafic content increasing with depth. Close to moderately spaced, horizontal breaks; typically undulating, rough, fresh to discolored, and partially open to open. Core times: 2:30/2:10/2:15/ 2:45/2:25 min:sec/ft.	
10							0.0		——11.0	
									Bottom of Exploration at 11.0 feet below ground surface. Boring terminated approximately 5 feet into rock.	
15										
20										
25										

Remarks:

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.


20516.00 BROOKLIN CULVERT
HB-BCR-101 11.0'-16.0' PEN = 60" REC = 56" RQD = 20/60 = 33%
HB-BCR-102 11.3'-15.9' PEN = 55" REC = 55" RQD = 25/60 = 45%
22548.00 SOUTHPORT CULVERT
HB-SCR-101 6.8'-11.8' PEN = 60" REC = 60" RQD = 54/60 = 90%
HB-SCR-102 6.0-11.0 PEN = 60 REC = 60" RQD = 42/60 = 70%


BCR-102
INCHES 1 2 LUFKIN 3 RUGGED 4 RED END 5 ENGINEERS 6 7 OIL 8 JOINTS 9 P.R. APP'D. 10 11


1F
1-1
1-2
1-3
1-4
1-5
1-6
1-7
1-8
1-9
1-10
1-11
2F


2-1
2-2
2-3
2-4
2-5
2-6
2-7
2-8
2-9
2-10
2-11


3-1
3-2
3-3
3-4
3-5
3-7
3-8
3-9
3-10
3-11
4-1


4F 4-1 4-2 4-3 4-4 4-5 4-6 4-7 4-8 4-9 4-10 4-11 5F 5-1

At-Rest Earth Pressures

$\beta := 0\ deg$ Slope angle of backfill soils from horizontal

$\phi := 32\ deg$ Assumed effective friction angle for granular borow (BDG Table 3-3)

$K_o := 1 - \sin(\phi)$

$K_o = 0.47$

Service Limit State Bearing Resistance

Nominal and factored Bearing Resistance

Presumptive Bearing Resistance for Service Limit State ONLY

Reference : AASHTO LRFD Bridge Design Specification 7th Edition, 2014
Table C10.6.2.6.1-1 Presumptive Bearing Resistances for Sprad Footings at
the Service Limit State Modified after US Department of Navy (1982)

Type of Bearing Material: Foliated metamorphic rock: slate, schist.
Consistency in Place: Hard Sound Rock - RQD = 70 to 90%.
Bearing Resistance: Ordinary Range (ksf) 60-80.
Recommended Value of Use: 70 ksf. - However we recommend 20 ksf as a maximum value.

Recommended Value: 20 ksf = 10 tsf

Note: This bearing resistance is settlement limited (1 inch) and applies only to the service limit state.

Strength Limit State Bearing Resistance

Determine Bearing Resistance cast-in-place concrete footing on bedrock using RMR method from AASHTO LRFD Section 10.4.6.4 Rock Mass Strength

References
1. AASHTO LRFD Bridge Design Specifications, 6th Edition, 2012
2. Wylie, Duncan C., "Foundations on Rock", Second Edition 2009
3. Hoek, E. and Brown, E.T., "The Hoek-Brown Failure Criterion - A 1988 Update", 1988

Rock is Cape Elizabeth Formation (Oce), Interbedded pelite and limestone, and/or dolomite.

RQD of samples were 70% and 90%.

Determine RMR from Table 10.4.6.4-1: Geomethanics Classification of Rock Mass.

1. Strength of intact rock material - see TABLE 4.4.8.1.2B Standard Specification 17th Ed., 2002. Typical Range of Uniaxial Compressive Stregth (C_o) as a Function of Rock Category and Rock Type.
   Type E - Coarse-grained igneous and metamorphic crystalline rock
   Gneiss (closest approximation) qu = 500-6500 ksf or 3,500 - 45,000 psi
   Values to Use - qu = 1,250 ksf or 8,680 psi

   From LRFD Table 10.4.6.4-1, 1080-2160 ksf, Relative Rating = 7

2. Drill core quality RQD - from Table 10.4.6.4-1, 70%, 90%, Relative Rating = 20, 25

3. Spacing of Joints - from Table 10.4.6.4-1, 2" to 1', Relative Rating = 10

4. Condition of Joints - from Table 10.4.6.4-1, joints open .05-0.2 inc., continuous joints, Relative Rating = 6

5. Groundwater conditions - from Table 10.4.6.4-1, moist only, Relative Rating = 7

From Table 10.4.6.4-2 Geomechanics Rating Adjustment for Joint Orientations, Fair = -7.

Adjusted RMR = 43

Table 10.4.6.4-3 Geomechanics Rock Mass Classes Determined from Total Ratings, RMR 60-41, Class No. III, Fair Rock.

Determine Rock Type from TABLE 10.4.6.4-4:

Rock Type E - Coarse grained polymierallic igneous & metamrphic crystalline rocks - Fair Quality Rock Mass.

Determine Rock Property Constants m and s:

Reference: "The Hoek-Brown Failure Criterion - a 1988 Update", Hoek, E. and Brown, E.T.

For intact rock, from Table 10.4.6.4-4, Type E $m_i := 25.00$

For a disturbed rock mass

$$RMR := 43$$

$$m := m_i \cdot \exp\left(\frac{RMR - 100}{14}\right) \qquad m = 0.426$$

$$s := \exp\left(\frac{RMR - 100}{6}\right) \qquad s = 7.485 \cdot 10^{-5}$$

Determine Nominal and Factored Bearing Resistance of Bedrock:

$C_{f1} := 1.0$ from Willie, Table 5.4, pg. 138 for Strip Foundation

$q_{uc} := \begin{bmatrix} 3500 \\ 45000 \end{bmatrix} psi$ AASHTO Table 4.4.8.1.2B, lower to upper bounds for gneiss

Nominal Bearing Resistance

$$q_{nom} := C_{f1} \cdot \sqrt{s} \cdot q_{uc} \cdot \left(1 + \sqrt{m \cdot s^{-.5} + 1}\right)$$

$q_{nom} = \begin{bmatrix} 35 \\ 454 \end{bmatrix} ksf$ from Willie Equation 5.4, pg. 138

Factored Bearing Resistance - Strength Limit State:

Use resistance factor of 0.45 for footings on rock, LRFD Table 10.5.5.2.2-1

$$\phi_{bc} := 0.45 \qquad q_f := q_{nom} \cdot \phi_{bc}$$

$$q_f = \begin{bmatrix} 16 \\ 204 \end{bmatrix} ksf$$

Use 16 ksf for Strength Limit State